Risk-Based Deep-Draft Channel Design

Michael J. Briggs, Zeki Demirbilek, Andrew Silver, and Ian Mathis

USACE Asset Management

Risk and Reliability Workshop

Alexandria, VA

15-18 Aug 06

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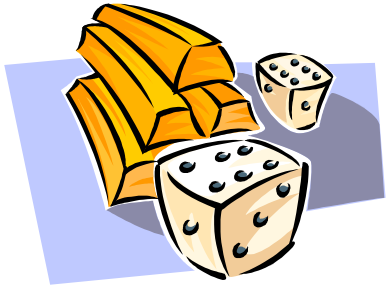
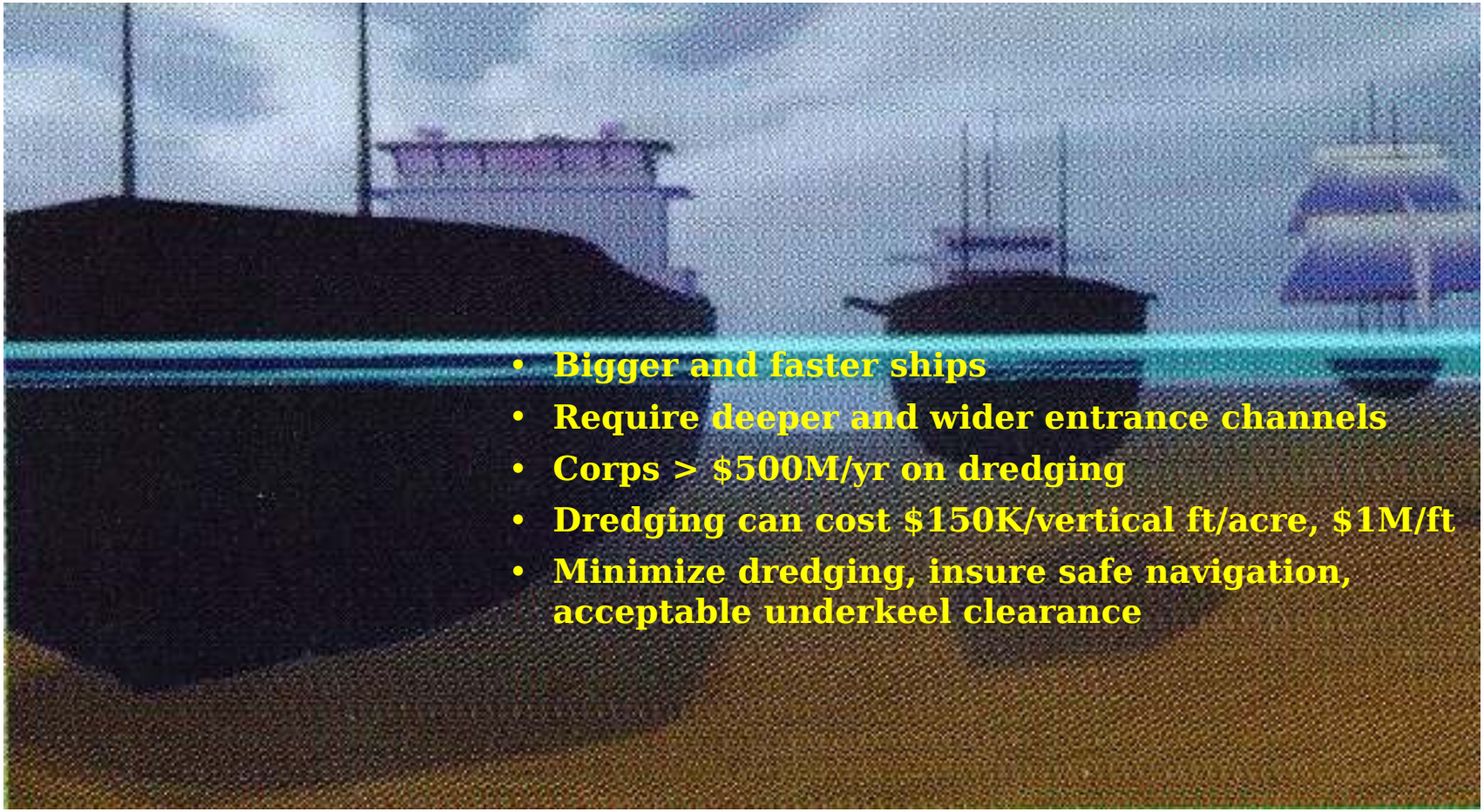


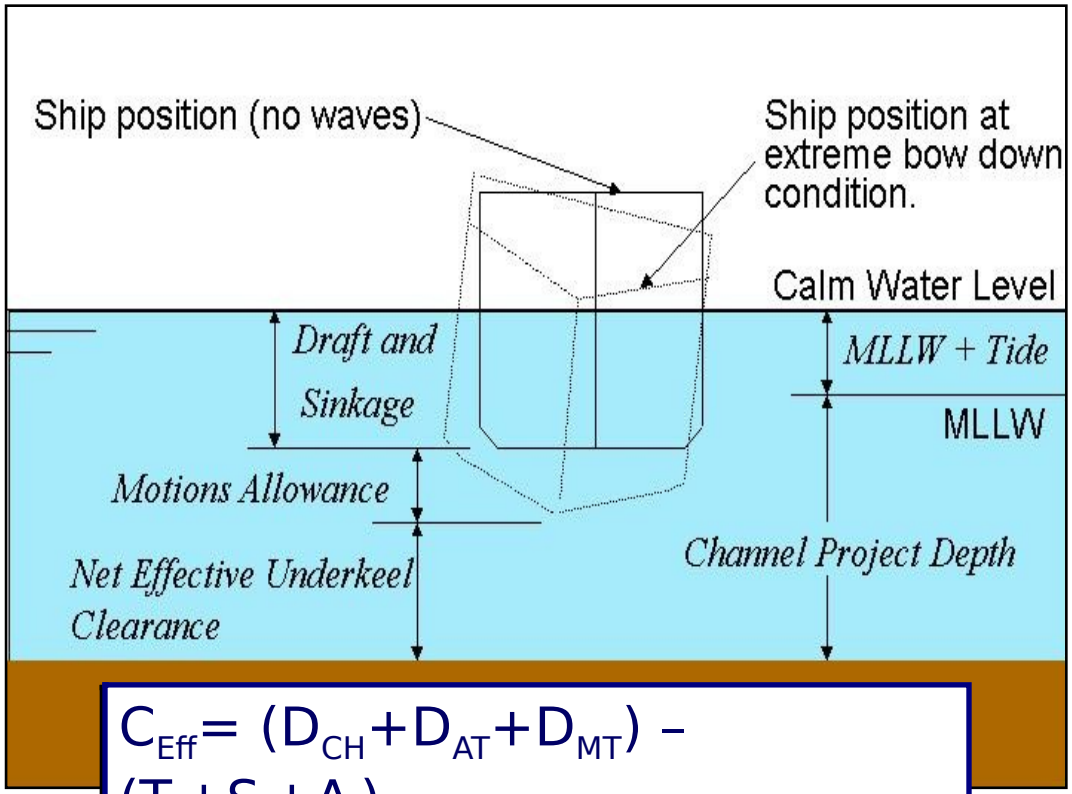
Problem



- Bigger and faster ships
- Require deeper and wider entrance channels
- Corps > $500M/yr on dredging
- Dredging can cost $150K/vertical ft/acre, $1M/ft
- Minimize dredging, insure safe navigation, acceptable underkeel clearance

Underkeel Clearance (UKC)

- **Net effective underkeel clearance C_{Eff}**
- **Channel project depth D_{CH}**
  - **Advance maintenance**
  - **Variability from horizontal**
- **Tide Stage**
  - **Astronomical D_{AT}**
  - **Meteorological D_{MT}**
- **Ship**
  - **Draft T_J (brackish)**
  - **Sinkage (Squat) S_J**
- **Motions allowance A_J**

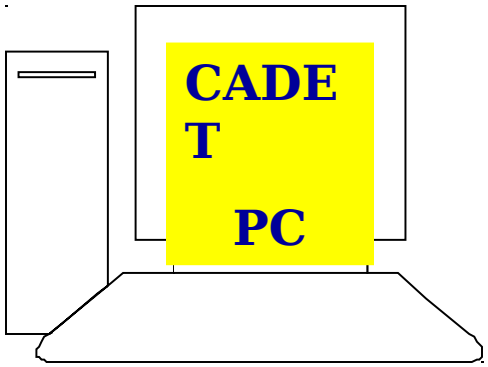


Background

- **Corps responsible for navigation safety**
- **Underkeel clearance (UKC) major factor**
- **No consistent guidelines for channel design**
  - **Corps**
  - **States**
  - **PIANC**
- **Ship motion data scarce**
  - **Physical model**
  - **Field measurements**
- **Analytical/numerical models**
  - **Few available**
  - **Little verification**
  - **Need probabilistic or risk-based models**

Overview

- Creation of a PC-based entrance channel design tool
  - Channel Analysis and Design Evaluation Tool (CADET)
- Based on Navy's Environmental Monitoring and Operator Guidance System (EMOGS)
  - Operationally assist deep draft Navy ships transiting shallow channels
  - Predicts underkeel clearance before the ship transits the channel
- Flexible to accept any commercial ship and any entrance channel design
- Bundle with software that calculates sinkage (squat) and trim and ship response amplitude operators (RAO's) for shallow water
- Fortran and C
- Operational in FY05
- Revisions in FY07, plans to market CADET



History of EMOGS Development

- **1989: Kings Bay for OHIO class submarine & wave buoys**
- **1992: VANGUARD class submarines**
- **1994: PC-based and pressure array**
- **1995: installed at Port Canaveral using wave buoys from Kings Bay**

Channel Design Methodology

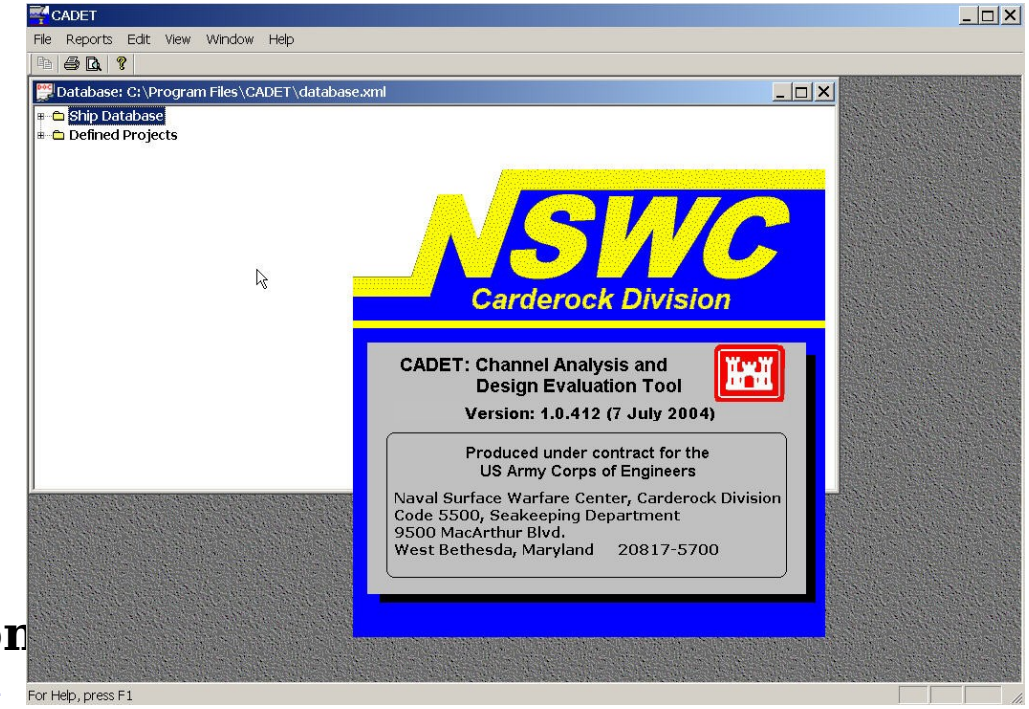
- **Deterministic approach**
  - **Required channel depth is calculated**
  - **100% accessibility**
- **Probabilistic risk-based approach**
  - **Predictions of net effective underkeel clearance**
  - **Analysis of associated risk of touching channel bottom for interpreting clearance output**
- **Accessibility Comparison – San Diego**
  - **Deterministic: Recommended channel depth 61 feet**
  - **EMOGS San Diego: Recommended channel depth 55 feet**
    - **90% accessibility with EMOGS channel operation guidance**
    - **62% accessibility without EMOGS channel operation guidance**
    - **Economic benefits of risk-based approach vs. deterministic**

Risk Analysis

- **Engineering Approach**
- **Model uncertainty with Gaussian distribu**
  - **Channel depth**
  - **Static ship draft**
  - **Sinkage (squat) and trim**
- **Model uncertainty with Rayleigh distribution**
  - **Motions allowance**
- **Risk of touching project depth**
  - **Proportion of all transits, under statistically constant conditions, where the minimum instantaneous clearance is less than zero**
  - **Probability density of the largest motion excursion in a given duration of transit considering uncertainty in estimates of channel depth and ship motion and velocity**
  - **Probability density obtained numerically**

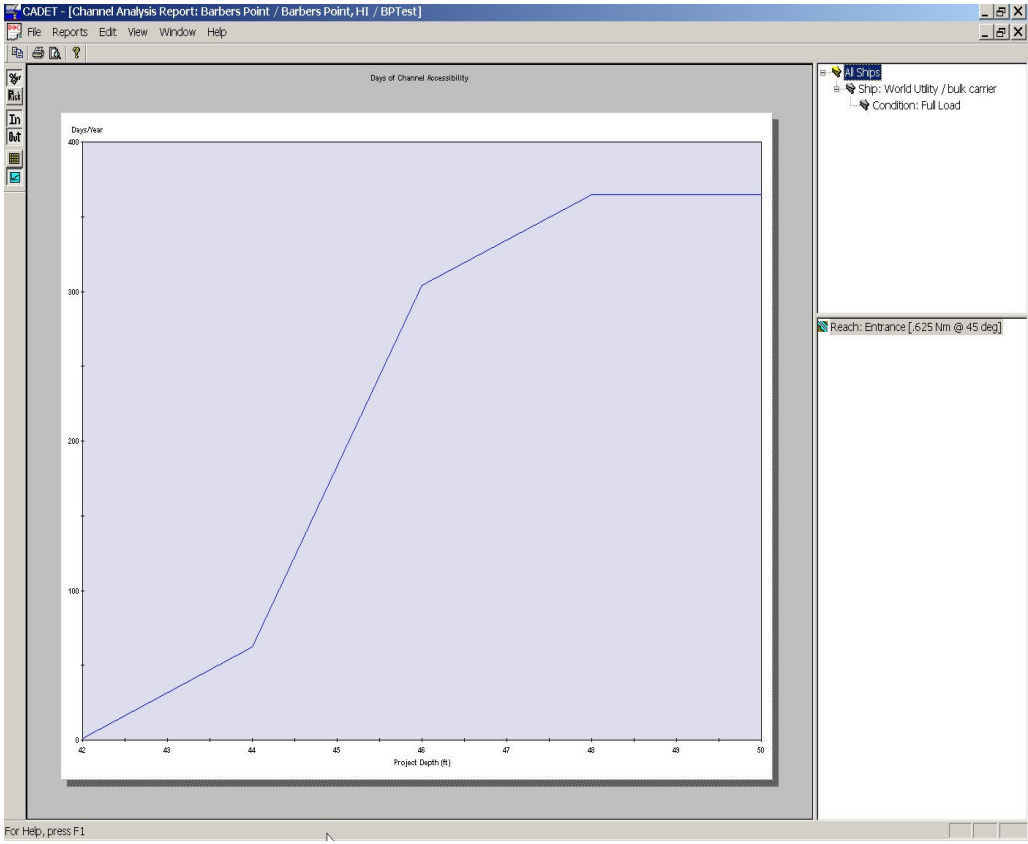
CADET Capabilities

- **Ship type and number**
  - **Containership**
  - **Bulk carrier**
- **Ship loading**
  - **Static draft and trim**
  - **Ship speed**
  - **CG**
  - **Roll damping**
  - **Roll and pitch gyradii**
  - **Sinkage (Squat)**
  - **6 DOF RAO's**
- **Inbound and outbound transits**
- **Any channel configuration**
  - **Channel segment length**
  - **Depth**
  - **Orientation**
- **Any wave conditions**
  - **Wave Spectra**
  - **Probabilities of occurrence**


CADET
File Reports Edit View Window Help
Database: C:\Program Files\CADET\database.xml
Ship Database
Defined Projects
NSWC
Carderock Division
CADET: Channel Analysis and Design Evaluation Tool
Version: 1.0.412 (7 July 2004)
Produced under contract for the US Army Corps of Engineers
Naval Surface Warfare Center, Carderock Division
Code 5500, Seakeeping Department
9500 MacArthur Blvd.
West Bethesda, Maryland 20817-5700
For Help, press F1

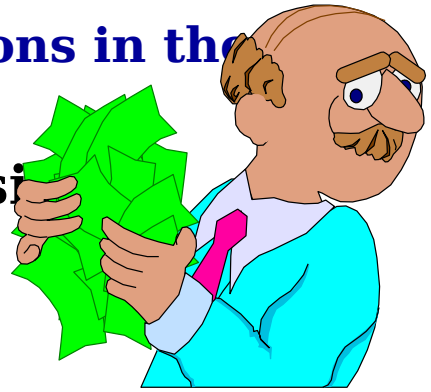
CADET Accessibility

- **Days per year can safely transit channel for given depth**
- **Based on percent occurrence of wave conditions per year yielding less than risk of touching specified project depth**
- **Selected ship and project**
- **Inbound and/or outbound transits**
- **Graph or table**



CADET Benefits

- **Planning & design for navigation studies**
- **Improved channel design for depth and alignment**
- **Predictive tool for squat, trim, RAO's, and UKC**
- **Operational tool for Corps, USCG and Port Authorities**
- **Minimum channel depth with maximum accessibility**
  - **Project depth can be minimized**
- **Improved operational efficiency**
  - **Determine when the environmental conditions in the channel are unsafe for transit**
- **Integrated models into NAV/MTS 2020 Visi**



Workshop Questions

- **Define and Prioritize Problems/Issues**
- **Data Assembly Questions**
- **Short and Long Term Goals**
- **Action Steps for High Priority Goals**

Problem Statement

- **Need good ship response data from field and laboratory for validation and verification of CADET and other numerical models**

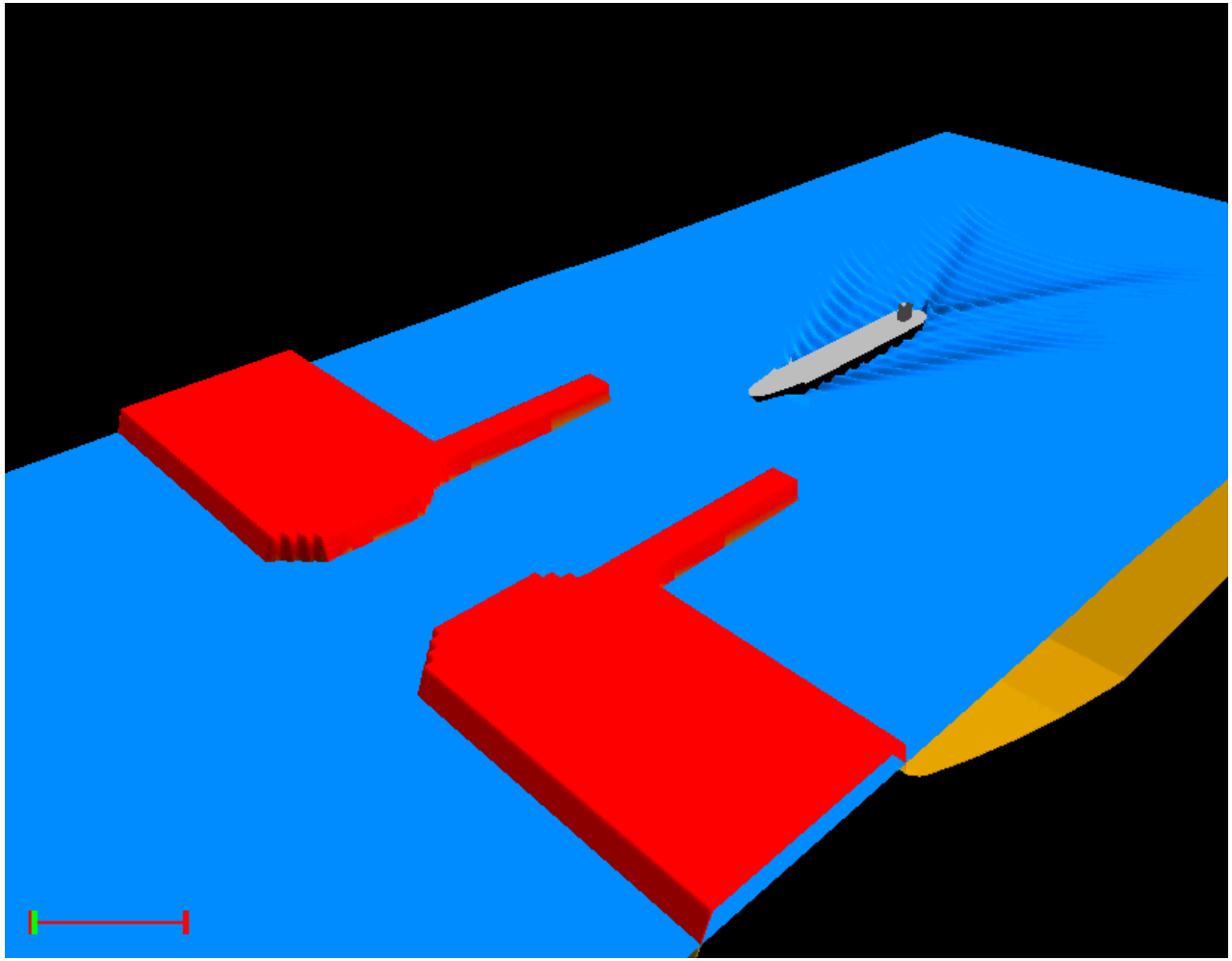
Data Assembly

- **What are data requirements?**
  - **Ship motions in 6 degrees of freedom to waves and currents**
  - **Ship sinkage or squat for new mega containerships coming on line**
- **What do we know and what do we need to know?**
  - **Have lots of empirical formulas for sinkage and squat, but are they accurate for larger vessels**
  - **Have RAOs for limited set of ships, but are the accurate for larger, commercial vessels**
  - **Can numerical models predict accurately or will they also need updated data from field or laboratory?**
  - **New 6 DOF models, Boussinesq models, RANS models for predictions**
    - **Phase-resolving wave modeling technology to predict waves and currents**
    - **Accurate and reliable estimate of waves at inlets and navigation channels, and wave runup and overtopping at inlet structures (jetties, breakwaters, piers**
  - **Field data is best (especially with GPS), but not always easy to obtain (weather, waves, ships, timing, etc.) and expensive to gather**

Short and Long Term Goals

- 1 Year Goals
  - Revised CADET Program
  - Continue validation studies
- 5 Year Goals
  - Better data on ship response including heave, pitch, roll, and squat
  - Better ship motion response programs for horizontal and vertical motions
  - RANS and Boussinesq models of ship response
    - A new finite-volume Boussinesq-type wave model with unstructured finite element grid
  - More comparisons with field and laboratory data
  - Active marketing of CADET

Ship-wake Effects at a Coastal Inlet



Action Steps

- Collect accurate ship sinkage and motion data from field and/or laboratory
- Data required
  - Range of wave conditions including periods, heights, and directional spread
  - Range of ship types, drafts, speeds, and angle of ship approach to waves
  - Range of current conditions
  - Range of channel conditions including restricted and unrestricted, channel side slopes, underkeel clearance
- Collaborators
  - ERDC, CHL
    - Navigation R&D
    - CIRP
  - IWR, NETS
  - NSWC, Carderock
- Consequences/Benefits
  - Better estimates of ship response to waves and currents
  - Inability to validate and verify model predictions
- Obstacles/Road Blocks
  - Funding

Summary and Conclusions

- **CADET: Channel Analysis and Design Evaluation Tool**
  - Ship type, number, and loading
  - Inbound and outbound transits
  - Any channel configuration
  - Any wave conditions
- **Determine when the environmental conditions in the channel are unsafe for transit**
  - Minimum channel depth with maximum accessibility
  - Predictive tool for squat, trim, RAO's, and UKC
- **Workshop Questions**
  - Problem/Issue Statement
  - Data Assembly
  - Short and Long Term Goals
  - Action Steps

Questions

- **Michael J. Briggs, Ph.D., PE**
- **Research Hydraulic Engineer**
- **Coastal and Hydraulics Laboratory**
- **Vicksburg, MS 39180**
- **601-634-2005**
- **Michael.j.Briggs@erdc.usace.army.mil**